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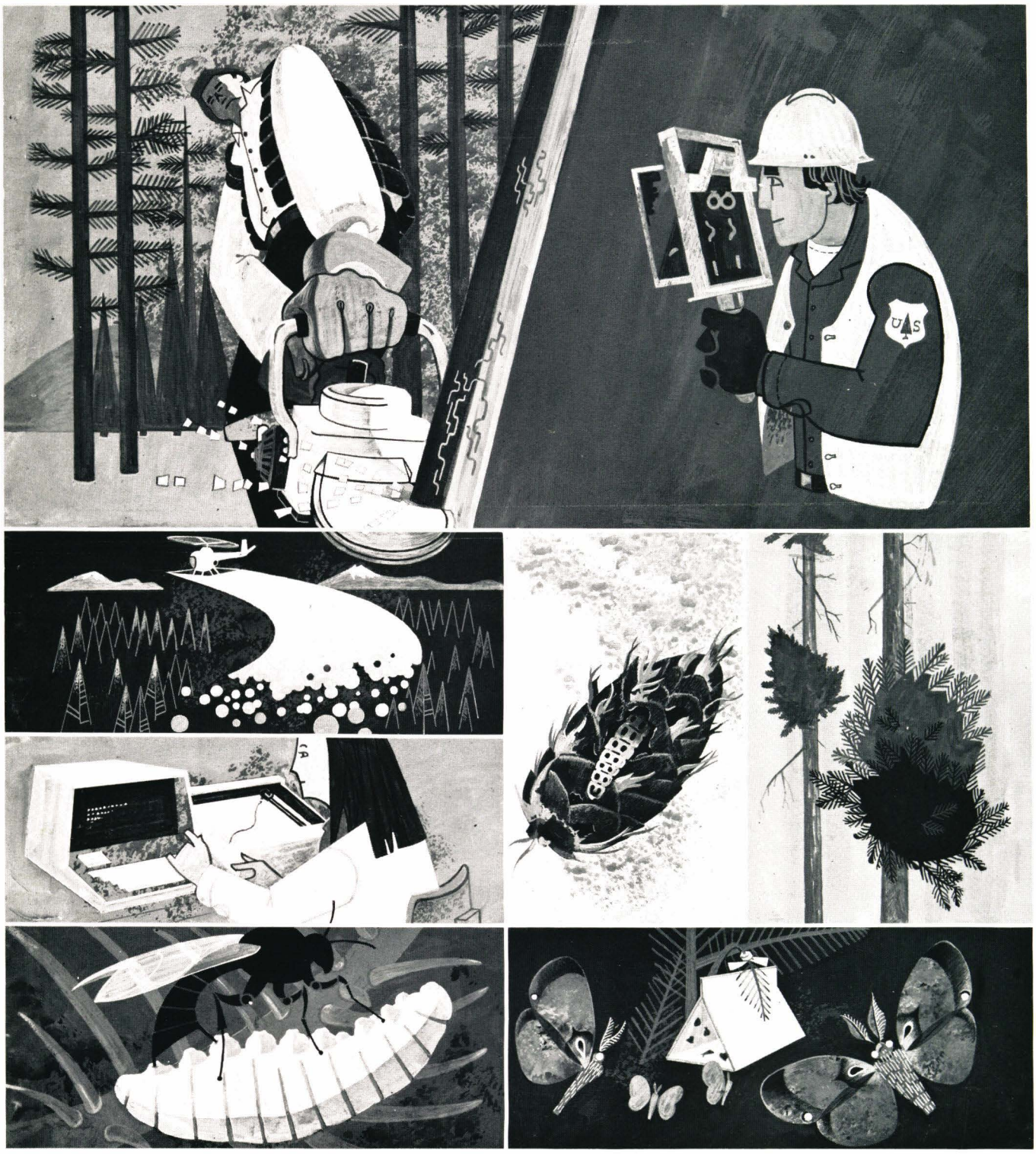
FOREST DECLINE INVENTORY METHODS IN WEST GERMANY: OPPORTUNITIES FOR APPLICATION IN NORTH AMERICAN FORESTS.



CONTENTS

INTRODUCTION ---------- 1

THE EUROPEAN FOREST DECLINE SYNDROME ---------- 3
SYMPTOMS ---------- 3
CAUSAL AGENTS ---------- 8

INVENTORY METHODS ---------- 9
GROUND SURVEYS ---------- 9
AERIAL PHOTOGRAPHY ---------- 13
DIGITAL IMAGE ANALYSIS ---------- 22

DISCUSSION ---------- 24
EUROPEAN VERSUS NORTH AMERICAN FORESTS ---------- 24
OPPORTUNITIES FOR APPLYING WEST GERMAN INVENTORY METHODS ---------- 25
INTERPRETATION OF DECLINE DATA ---------- 27

ACKNOWLEDGMENTS ---------- 27

LITERATURE CITED ---------- 28

Report No. 86-3

3400

April 1986

FOREST DECLINE INVENTORY METHODS IN WEST GERMANY: OPPORTUNITIES FOR APPLICATION IN NORTH AMERICAN FORESTS

by

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ABSTRACT

Inventory methods used to assess the status of forest decline, believed to be caused by atmospheric deposition of pollutants, in West Germany are reviewed. Nationwide forest damage statistics for West Germany are presently based on a network of ground plots. A five class damage rating system, based on foliage loss and condition is used to classify sample trees. Extensive use of large scale color infrared (CIR) aerial photography is being made for statewide, regional, and local forest decline inventories, assessing patterns of decline relative to pollutant sources and topographic features, and damage trend surveys. Photographic parameters, photo interpretation techniques, survey designs, and operational problems associated with acquisition of aerial photos and accompanying ground data are described. Research is underway at several facilities to investigate the use of computer assisted classification of digital airborne MSS data and Landsat TM data to detect and classify damage.

Opportunities for applying inventory techniques presently used in West Germany to assess status of forest decline and damage in the United States is discussed in light of commonalities and differences between North American and European forest ecosystems and management intensities.

INTRODUCTION

Since the late 1970's, a regional decline affecting many tree species has occurred in Europe. This decline has been most intensively studied in the Federal Republic of Germany (West Germany) but has also been reported from

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[2/]Partial funding for this work was obtained through the USDA Office of International Cooperation and Development (OICD).

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Austria, Belgium, France, Switzerland, and several other central and eastern European nations. The decline was initially termed "Waldsterben" (Forest death) and more recently "Neuartige Waldschaden" (a new type of forest damage), and has been widely reported in scientific and popular literature both in Europe and North America. General reviews are provided by Schutt and Cowling (1985), Niesslein and Voss (1985), Plochmann (1984), and Steinbeck (1984).

The complex of stress factors responsible for inducing this decline syndrome are not fully understood. However, several hypotheses have been formulated in an attempt to explain its causes. Most consider the atmospheric deposition of toxic, nutrient, acidifying, and/or growth altering substances as an inciting factor (Schutt and Cowling 1985). The European forest decline has also been of interest to resource managers and the general public in North America because of recent concerns over the adverse effects of acid rain and other atmospheric pollutants on terrestial and aquatic ecosystems. Of particular interest are several recent forest declines which have been reported in the eastern United States and Canada. The potential role of atmospheric deposition of pollutants as inciting factors in at least one of these, a decline of red spruce, Picea rubens, has been discussed by several workers (Friedland et al. 1984; Johnson and Siccama 1983; Siccama et al. 1982).

Beginning in 1982, the West German Federal Ministry of Food, Agriculture, and Forestry initiated a nationwide inventory to provide annual data on the status and trend of forest decline (Anonymous 1984b). In addition, several West German states have initiated surveys to provide additional data. These inventories involve both ground surveys and remote sensing. Efforts are currently underway to design and conduct surveys for acquisition of similar data in the United States.

During September 1985, the senior author visited a number of sites in West Germany to study forest damage inventory methods currently in use. Objectives of this visit were to:

1. Study the symptoms of forest decline on various commercial tree species and the appearance of these symptoms on large scale color and color infrared aerial photographs.

2. Participate, to the extent possible, in all aspects (photo interpretation, ground checking, data analysis) of a scheduled re-inventory of forest decline in at least one West German state.

3. Review current research and development in use of advanced remote sensing technology to classify and map forest decline and mortality.

This report is a review of forest decline inventory methods currently in use in West Germany and an evaluation of their potential applicability to North American forests.

THE EUROPEAN FOREST DECLINE SYNDROME

SYMPTOMS

The European forest decline syndrome consists of many symptoms. Symptoms are progressive and often lead to tree mortality. They have been reported on virtually every commercially important tree species. Schutt and Cowling (1984) classify decline symptoms into three broad groupings; growth decreasing, abnormal growth, and water stress. Growth decreasing symptoms include foliage loss, feeder root mortality, reduction in radial increment, premature senescence, loss of needles and leaves, and tree mortality. Abnormal growth symptoms include abscission of green foliage and shoots, altered leaf and branch morphology, and abnormally heavy seed and cone crops. Water stress symptoms include the formation of bacterial wetwood. A number of illustrated guides have been published which describe decline symptoms on the major native and introduced tree species (Anonymous 1984a; Schroter and Aldinger 1985). Crown symptoms, which were observed on several commercially important species during this visit and which are used in damage rating systems, are described in the following sections.

NORWAY SPRUCE, Picea abies (L.) - Norway spruce, a tree widely distributed throughout northern Europe (Quartier 1978), is the most important commercial tree species in West Germany, comprising about 42 percent of the total forest area (Anonymous 1984b). A wide range of decline symptoms occur on Norway spruce including loss of foliage, foliar discoloration, loss of increment, and tree mortality. Detailed descriptions of crown symptoms of decline in Norway spruce have been published in several sources (Schroter and Aldinger 1985; Hartmann, 1984; Anonymous 1984a).

The most widespread symptom of decline of Norway spruce is a loss of foliage and a thinning of the crown (Fig. 1). Several patterns of foliage loss are described by Schroter and Aldinger (1985). The "Larchen-Typ" (Larch Type) consists of a more or less overall thin appearance to the crown with greatest foliage loss occurring in the lower crown. In the "Fenster-Typ" (Window Type), foliage loss is concentrated on the inner portions of the crown, giving the tree a tufted appearance.

Foliage loss may be accompanied by branch dieback, which is often concentrated just below the tip of the crown, and is referred to as sub-top dieback. Top dieback, which is commonly associated with repeated outbreaks of conifer defoliating insects in North America, is also part of the decline syndrome on spruce in Europe. Dead or defoliated branches often have a profuse growth of lichen.

Another symptom is a chlorosis of the older foliage. This symptom can be seen in many spruce stands at mid and upper elevations throughout West Germany. The yellow discoloration tends to be most conspicuous on the upper needle surface and is generally confined to the older needles. In 1985, the most typical pattern of chlorosis was a yellowing of needles three years old and older. A red-brown discoloration of spruce foliage is also reported but is not as widespread as the chlorosis. This type of discoloration occurs on

Figure 1 - Progressive stages of decline in Norway spruce, Picea abies. A. Tree in early decline stages (class 1). Note thinning of branches in upper crown. 2. Tree in more advanced stage of decline (class 2) characterized by branches which have a tufted appearance indicative of loss of older foliage. C. Final stages of decline (class 3) characterized by a preponderance of dead branches and presence of epicormic branches.

the current years growth, similar to that reported for red spruce in the Northeastern United States (Friedland et al. 1984), and the older foliage.

SILVER FIR, Abies alba Mill. - Silver fir is a tree of mid-elevation slopes that is distributed from France and southern Germany south to Italy and the Balkans (Quartier 1978). Crown symptoms of decline are described in detail by Schroter and Aldinger (1985).

Early stages of decline are characterized by a loss of the older foliage. This is often followed by the formation of a storks nest in the tip of the crown which is perhaps the most striking of the European forest decline symptoms. The storks nest is formed as the result of a marked reduction in height growth of the leader accompanied by normal or nearly normal growth of the lateral branches. This causes a characteristic flattening of the upper crown. Storks nest formation is apparently normal in silver fir after trees reach age 100 (Quartier 1978); however, since the late 1970's, storks nests have begun to appear on younger trees as well. Branch dieback begins to appear in the crown, especially in the area directly below the storks nest (Fig. 2). A profuse growth of lichen develops on the dead branches. Epicormic branches form on the mid and lower crown. Both red and yellow needle discoloration has been reported on silver fir, but at a much lower frequency than on Norway spruce.

Many of the symptoms associated with the decline of silver fir have appeared periodically on the north side of the Alps during the past 250 years. This condition has been described in the literature as "Tannensterben" (fir death) (Kandler 1985). The occurrence of Tannensterben is presently much more widespread and intense than was reported during past episodes however (Schutt and Cowling 1985).

BEECH, Fagus sylvatica L. - Beech is the most widespread and commercially important hardwood in West Germany. Decline symptoms are more subtle on beech than on spruce or fir. Abnormal branching, loss of foliage, premature shedding of leaves, foliage discoloration and necrosis, leaves with irregular margins, and branch dieback are among the symptoms reported associated with decline of beech (Schutt and Cowling 1984). Detailed descriptions of crown symptoms are provided by several sources (Anonymous 1984a; Runkel and Roloff 1985).

Early crown symptoms include an overall thinning of the foliage which is typically dense on a healthy, vigorous tree. This is followed by the occurrence of individual branches along the margin of the crown which have a characteristic spear or clawlike appearance. In advanced stages, the crown has an open character and branch dieback is common (Fig. 3).

SCOTS PINE, Pinus sylvestris L. - Scots pine is widely distributed in Europe and Asia (Quartier 1978) and extensively planted in Germany, especially in the northern states. Symptoms of decline on this species resembles those of chronic sulfur dioxide or ozone fumigation (Schutt and Cowling 1985). Decline symptoms and biotic factors which mimic decline symptoms on Scots pine are described by Hartmann (1984).

Figure 2 - Progressive stages of decline in silver fir, Abies alba. A. Early stages of decline (class 1). Note decreased height growth beginning to result in a flattened crown and formation of a storks nest. B. A class 2 tree characterized by presence of a distinct storks nest and a thinning of foliage in mid and lower crown. C. Class 3 tree with all of the primary crown, including the storks nest, noticeably thin or dead, and presence of epicormic branches.

Figure 3 - Beech with branch dieback in upper crown.

The most striking crown symptom on Scots pine is a loss of older foliage giving the crown a thin, transparent appearance. Healthy Scots pine normally retains three to four years of foliage. Declining trees tend to lose the oldest needles first causing trees to have a thin, tufted appearance. Foliage loss is often accompanied by shorter than normal needles, especially in the lower crown.

A number of biotic factors are known to cause a crown thinning in Scots pine. Portions of new shoots which produce staminate flowers in spring do not produce needles. During years of heavy staminate flower production, Scots pine tends to have a thin appearance, especially in the lower crown where flower production is heaviest. Branches which produce staminate flowers are said to have a pagoda like appearance with alternating bands of needles and areas of missing foliage. Several insects and fungi are also known to be associated with crown symptoms in Scots pine. A needle cast fungus in the genus Lophodermium caused defoliation from 1979-82 in Scots pine forests in the Luneburg Heath Region of Lower Saxony. This was followed by infestation of pine needles by a gall midge, Contarina baeri and a prolonged drought. The stands recovered in 1984-85 following a collapse of these insects and a return to normal moisture levels. In addition, a rust fungus, Endocronartium pini produces a canker which causes top kill in Scots pine and is referred to as Kienzopf. Maturation feeding in lateral branches by the adult stage of a barkbeetle, Blastophagus piniperda, causes the upper crown to have a thin, spindley appearance. This damage was especially noticeable in low elevation Scots pine forests in Bavaria in 1985.

CAUSAL AGENTS

As is the case with the forest declines that have been reported in North America, the specific causal agents responsible for producing the symptoms associated with the European forest decline syndrome are not clearly understood. With the possible exception of Scots pine, classic biotic agents such as insects or fungi, while present at low levels, have not been isolated from symptiomatic trees except as secondary invaders. Most workers generally agree that some type of anthropogenic pollutant is involved. Six general hypotheses have been formulated to explain the symptoms. These are described in detail in the literature (Schutt and Cowling 1985; Courtois 1984, 1985; Niesslein and Voss, 1985) and are simply listed here:

1. Increased acidification of forest soils due to deposition of acidic substances from the atmosphere. This results in increased concentrations of soluble aluminum ions which in turn causes death of fine roots.

2. Increased levels of ozone in the atmosphere in various parts of West Germany result in foliage loss and growth reduction.

3. Yellowing of spruce foliage is the result of magnesium deficiencies in soils that have adequate supplies of nitrogen and calcium. Acid deposition may accelerate leaching of calcium and magnesium from foliage and soils.

4. Increased air pollution levels in recent years has led to a decrease in net photosynthesis and reduced nutrient reserves making trees more susceptible to drought and other stresses.

5. Heavy deposits of excess nutrients, especially nitrogen which causes increased growth and demand for other nutrients, increases susceptibility to drought, invasion by root disease fungi, and a loss of mycorhizal fungi.

6. Air transport of growth-altering organic substances.

Kandler (1985), on the other hand, tends to reject the hypothesis of abiotic factors such as atmospheric pollutants as causal agents of the current wave of forest decline and proposes an alternative "epidemic" hypothesis. He postulates that each of the decline symptoms, i.e., fir decline, chlorosis of spruce foliage, loss of spruce foliage, may be the result of a separate and distinct complex of environmental and very likely, unknown biotic factors. He bases this hypothesis on the fact that several of the decline symptoms, such as fir decline and foliage loss in spruce, have been reported previously in the literature. Episodes of silver fir decline, for example, were described as early as 1885 when levels of sulfur dioxide were much lower than they are today. In addition, the sudden, widespread appearance of chlorotic foliage on Norway spruce in 1980 was not accompanied by a corresponding increase in levels of anthropogenic pollutants.

INVENTORY METHODS

Both aerial and ground survey methods are used in West Germany to assess the status of forest decline. The primary objective of these surveys is to assess the condition of living trees and not to inventory tree mortality. Inventory data on tree mortality is of little value because dead and dying trees are rapidly salvaged. In some areas up to 10 entries are made into stands annually to recover the mortality.

GROUND SURVEYS

Nationwide forest damage statistics for West Germany are presently based on ground surveys. Beginning in 1982, the Federal Ministry of Food, Agriculture, and Forestry initiated an inventory to assess the status of forest decline on a national basis. This first inventory was an informal process which consisted of field assessments by state forestry officials and questionnaires sent to key forest landowners. In 1983, a sampling procedure was developed which was used in several West German states. In 1984 all states used essentially the same sampling procedure for the nationwide inventory of forest decline (Anonymous 1984b). A reinventory was in progress in 1985.

SAMPLING PROCEDURE - Sample plots are established throughout most of the states on a 4 X 4 km grid. In areas where forest land is widely scattered, such as in parts of northern Germany, plots are located on a 2 X 4 or even a 2 X 2 km grid in order to obtain an adequate sample. In the state of Schleswig-Holstein, for example, a total of 200 plots were established in this manner.

A central reference point (Messpunkt) is established at plot center. Four subplots are established 25 meters from the Messpunkt in the cardinal

directions. The six trees nearest to the center of each subplot are selected and rated as to degree of decline for a total of 24 trees per plot. In addition, the following data are recorded for the plot and the sample trees:

1. Basic locational data: state, forest district, plot number, etc.

2. Stand data: age, topographic position, elevation.

3. Tree species or species group.

4. Incidence of known damaging agents such as insects, fungi, animals, etc.

The nationwide inventory is designed to provide essential data that can be collected by a limited staff without commitment of large amounts of additional funds. Forest lands in West Germany are heavily roaded, therefore, most forest decline plots are readily accessible. In the State of Schleswig-Holstein, a two-person field crew can complete the field data collection in three to four weeks, examining plots at the rate of two to three per day. In Baden-Württemberg, 28 two-person field crews and 6 supervisory personnel completed the inventory in 3 weeks. Plots are visited in August.

DAMAGE RATING - A general five class damage rating system, based on estimates of foliage loss, has been developed for the nationwide inventory and used since 1984 (Schroter and Aldinger 1985). This system is modified by narrative descriptions to apply to all tree species or species groups of commercial importance (Table 1).

Table 1 - Five class system for rating forest decline in West Germany.

Damage Class	Tree Status	Defoliation (%)
0	Healthy	0-10
1	Sickly	11-25
2	Sick	26-60
3	Very Sick	61-99
4	Dead	

A modified version of this rating system, which consists of a two variable matrix, was developed recently to account for the presence of discolored or chlorotic foliage as well as foliar loss (Table 2).

Table 2 - Modified two variable rating system used to rate forest decline in West Germany.

Defoliation %	Foliage Discoloration (%)			
	0-10	11-25	26-60	>60
	- Tree Rating -			
0-10	0	0	1	2
11-25	1	1	2	3
26-60	2	2	3	3
61-99	3	3	4	4
Dead	4	-	-	-

Since symptoms vary by species, narrative descriptions have been developed for damage classes 0-3 for each tree species or species group (Table 3; Anonymous 1984a; Hartmann 1984; Runkell and Roloff 1985). These descriptions begin with the definition of a healthy tree. Damage classes are described as progressive departures from a healthy or normal tree. The standards for a healthy tree are rigid; for example, shade tolerant trees such as Norway spruce or beech must be full crowned with dense foliage and little or no sunlight coming through the crown in order to receive a "Healthy" rating.

Damage ratings are given by a team of at least two observers who examine each sample tree from several observation points with binoculars. They discuss their individual observations during the rating process and arrive at a concensus for each tree.

DATA PRESENTATION - Data acquired as a result of the nationwide forest decline inventory are published annually by the Federal Ministry of Food, Agriculture, and Forestry. They are presented in tabular, narrative, and map form by damage class, state, tree species, and age class. Data include the proportion of trees and area for each major tree species or species group by damage class. No mensurational data such as numbers of trees per unit area, volumes affected, or growth rates are presented as a result of this survey. There is also no data presented on the status of decline in regeneration. Comparisons are made from one year to the next to provide indications of damage trend. For national reporting purposes, all trees rated in classes 1, 2, 3, and 4 are considered damaged (Anon. 1984b; Niesslein 1985), however, there is considerable disagreement among West German foresters as to whether or not trees in class 1 should be regarded as damaged.

The results of the nationwide inventories conducted to date indicate that the most severe damage is occurring in southern Germany, in the states of

Table 3 - Summary of narrative descriptions for ground classification of decline on four major West German tree species[1/].

Damage Class	Tree Species			
	Norway Spruce	Silver Fir	Beech	Scots Pine
0-Healthy	Foliage a deep green color. No chlorotic or yellow foliage present. Crown with a thick compliment of foliage. Little or no sunlight visible through crown. Branches and mainstem not visible throughout most of crown.	Foliage a rich green color. No chlorotic or yellow foliage present. Tip of crown with a distinct point on trees less than 100 years old. Some flattening of crown normal on older trees. Little or no sunlight visible through crown.	Rounded crown with dense foliage. Little or no sunlight visible through crown. Less than 10% foliage loss.	Foliage a dark green color. Trees retain 2 to 3 years of foliage in northern Germany; 3 to 4 years of foliage in southern Germany.
1-Sickly	Incipient crown thinning beginning in interior of crown, progressing outward. Secondary branches growing irregularly. Occasional lateral twigs partly defoliated and drooiping. Light needle yellowing usually of 2 or 3 year old needles.	Incipient crown thinning starting in interior of crown and progressing outward in lower and midcrown. (Crown has a transparent look.) Decreased height growth even in young trees. Incipient development of flat tops.	Individual spear or clawlike branches begin to appear along periphery of crown. Sparse foliage in peripheral crown area. Some yellowing of foliage.	Incipient thinning of crown beginning in interim and progressing outward. Incipient yellowing of crown. (Should not be confused with needle cast or nutrient related chlorosis.) Decreased growth of shoots and needles. Not more than 2 complete years of foliage present.
2-Sick	Thinning of entire crown. Lateral second order branches drooping and partly defoliated ("Tinsel effect"). Commonly concurrent yellowing and browning of older needles.	Severe thinning of lower and mid crown. Branch mortality in crown with heavy lichen growth. Dense, stout water sprouts. Upper crown fully foliated stands out (storks nest). Stunted terminal shoots with yellow needles occurring irregularly.	Distinct thinning of exterior region of crown. Leaf necrosis. Some branch dieback present.	Advanced thinning of crowns starting in the interior and progressing outward. Severe gray, yellow, or brown needle discoloration. One and only a partial second year's foliage present.
3-Very Sick	Severely thinned crown, branches visible throughout crown, many individual dead branches. Dead tops common. Resin flow from stem common in crown where needles are still present. Epicormic branching common. Yellow or brown foliage on 60% of crown.	Progressive defoliation until crown mortality occurs. Flat top storks nest dies only during terminal phase. Water sprouts often remain green after primary crown has died.	Mortality of a portion of the crown. Crown has an open appearance.	Mortality of a portion of the crown. All needles have become discolored. Only one year's foliage present.

[1/]This summary was compiled from published literature (Anon. 1984a; Hartmann 1984; Runkel and Roloff 1985), unpublished field guides, field observations, and discussions with West German Forestry officials.

Baden-Württemberg and Bavaria. In 1984, silver fir was the most severely affected species with 87 percent of the land area occupied by this species showing decline symptoms. Silver fir, which occurs naturally only in southern Germany, occupies only 2 percent of the total forest area of West Germany. Norway spruce, by comparison, which covers 42 percent of the forest area, had 51 percent of the area it occupies affected by decline symptoms. Comparison of 1983 and 1984 survey data shows an increase from 34 to 50 percent of the total forest area of all species affected by forest decline in 1984. Most of this increase was in damage class 1 which rose from 25 percent of the total forest area in 1983 to 33 percent in 1984 (Anon. 1984b). Data for 1985 were not available for review at the time of this visit.

AERIAL PHOTOGRAPHY

A number of approaches have been designed to inventory forest decline using color-IR aerial photography in West Germany. These approaches are based on research and experience with the use of color-IR photos for forest damage assessment in West Germany during the past two decades. In response to a request from the State Forest Service of Baden-Württemberg early in 1983, a sampling procedure using color-IR photos was designed for a statewide inventory of forest decline. This procedure has served as a model for statewide or regional inventories or surveys to provide data on the status of decline on a stand basis, evaluate patterns of damage relative to topographic features and pollutant sources, and obtain data on damage trends. The major advantage of aerial photography cited by workers in West Germany, is that aerial photos provide a permanent record of the status of forest decline at a specific point in time. Several overviews of the applications of aerial photography for assessment of the West German forest decline problem appear in the published literature (Hildebrandt and Kadro 1984; Hildebrandt 1985a) as well as descriptions of specific applications (Hartmann 1984; Kenneweg and Liesebach 1985; Nagel 1984; Hartmann et al. 1985; Tepasse 1984).

As is the case with ground inventories, emphasis on use of aerial photos for inventory of forest decline in West Germany is also on the assessment of the condition of living trees as opposed to quantification of tree mortality. This is in contrast to inventories of forest damage which have been conducted in the United States where emphasis has been on estimating numbers of trees killed and associated volume loss from outbreaks of coniferous barkbeetles or other damaging agents (Bennett et al. 1980; Ciesla et al. 1971; Klein et al. 1979; Stewart et al. 1982; Weiss et al. 1985;).

PHOTOGRAPHIC PARAMETERS - Aerial photo surveys conducted for forest decline in West Germany are flown with 230 mm (9-inch) metric mapping cameras by commercial contractors. Zeiss RMK[3/] mapping cameras with 30 cm (12-inch) focal length lenses are used almost exclusively. The only exception is in Bavaria where some aerial photography has been flown with a 60 cm (24-inch) focal length lens. Use of lenses with long focal lengths provide aerial

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3/Mention of commercial products is for convenience only and does not imply endorsement by USDA Forest Service.

photos with minimum edge displacement. In addition, some cameras are equipped with forward image motion compensation which results in aerial photos of exceptionally high resolution.

Kodak Aerochrome infrared film - Type 2443 (CIR) is used for all forest decline surveys. Film is processed by two commercial firms in West Germany. Some limited testing has been done in Bavaria with Kodak SO-131 high definition aerial Ektachrome infrared film.

A variety of photo scales are used by the various West German states. The most frequently used photo scales are 1:5000 and 1:6000; however, the range of photo scales is from 1:3000 to 1:16000 (Table 4) (Hildebrandt and Kadro 1984; Hildebrandt 1985a). The phenological period for aerial photo acquisition ranges from late May to early September. Late July to late August is the preferred time because of full foliage development, a better sun angle and less smoke and haze. Processed film is usually delivered to photo interpreters in late August and September. Photo annotation is done by the contractor.

PHOTO INTERPRETATION - Use of aerial photography for assessment of forest decline is dependent on the ability to extract two data elements from the photos: tree species and degree of damage.

SPECIES IDENTIFICATION - In comparison with North American forests, the forests of northern and central Europe have relatively few tree species. Most have unique characteristics which can be used to readily identify them on color-IR aerial photos using such criteria as foliage color and texture, crown apex and margin, and overall form. Similar criteria have been used to identify North American tree species on large scale aerial photos (Heller et al. 1964; Sayn-Wittgenstein 1978) and have been used in conjunction with inventories of forest decline in the United States (Ciesla 1984).

The major commercial West German conifers are easily identified on large scale color-IR aerial photos. Norway spruce is dark red-brown or red-violet in color. The branches are distinct and readily visible. The crown margin is deeply lobed giving it a starlike appearance, and the crown apex is distinct. Silver fir, on the other hand, is a deep rich red color with a finer branch and foliage texture. The crown apex is not clearly visible and the crown margin is serrate. Douglas-fir, Pseudotsuga menziesii, a North American conifer which is extensively planted in many parts of West Germany, is somewhat intermediate in appearance between Norway spruce and silver fir, having the distinct branches, crown apex, and lobed crown margin of Norway spruce, and the deep red foliage color of silver fir (Fig. 4). Scots pine has a deep red-brown foliage color but lacks the distinct crown apex and lobed margins of Norway spruce. European larch, Larix decidua, is a lighter red color with a fine foliage texture and a distinct crown apex which is often lighter in color than the rest of the crown.

Many of the commercially important hardwoods are also readily identified on large scale color-IR aerial photos although their crown characteristics are not as clearly identifiable as are the conifers. The crown margins of beech are dentate and the foliage has a fine texture. Oaks, Quercus spp., have a

Table 4 - Summary of aerial photographic parameters used by various West German states for inventory of forest decline during the period 1983-85[1/]

State	Photo Scale	Film Type	Lens Focal Length (cm)	Photo Acquisition Biowindow
Baden-Württemberg	1:5000	CIR-2443	30	late July
Bavaria	1:3000 1:5000 1:7000	CIR-2443 CIR SO-131[2/]	30 & 60	late July - late August
Hessen	1:4500	CIR-2443	30	early May - late August
Lower Saxony	1:6000	CIR-2443	30	late July - early August
North Rhein - Westfalen	1:5000	CIR-2443	30	late July - early August
Rheinland-Pfalz	1:5000 1:2500	CIR-2443	30	early September
Saarland	1:16000	CIR-2443	30	late July
Schleswig-Holstein	1:6000	CIR-2443	30	mid July to mid August
Hamburg	1:4000	CIR-2443	30	no information available

[1/] Compiled from Hildebrandt and Kadro (1984), Hildebrandt (1985a), and discussions with West German forestry officials.

[2/] CIR SO-131 Kodak High Definition Aerochrome IR was evaluated on a small area test only.

clustered pattern of foliage and branches which is said to resemble a head of cauliflower. European birch, Betula pendula, is a somewhat darker red color than beech or oak and has a finer foliage texture than the other hardwoods.

RATING TREE DECLINE - Individual trees are rated on large scale color-IR aerial photos using the same rating system used for ground inventories. Photo interpretation keys, which include both narrative descriptions and illustrations for each damage class, have been developed for the major West German commercial tree species (Grundmann 1984; Hartmann 1984; Loffler et al. 1984; Masumy 1984; Runkel and Roloff 1985).

As Norway spruce begins to express early symptoms of decline, crown color shifts from the rich red-brown or red violet color typical of a healthy tree,

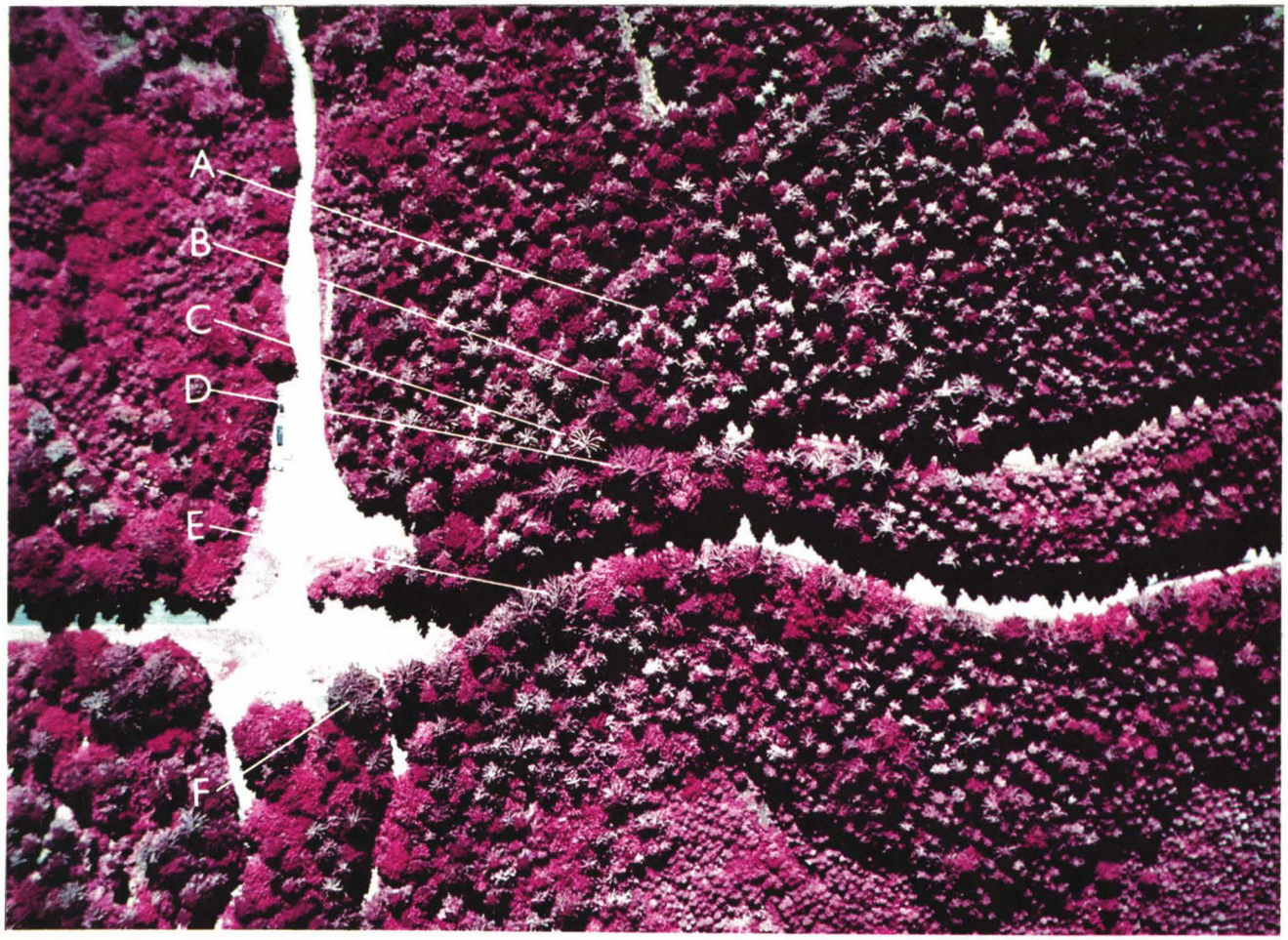

Figure 4 - Section of a color-IR aerial photo from the Black Forest showing trees in various stages of decline. A. Silver fir with storks nest surrounded by dead branches (class 2). B. Healthy silver fir (class 0). C. Norway spruce in final stages of decline (class 3). D. Healthy Douglas-fir. E. Norway spruce with chlorotic folage (class 2). F. Norway spruce in early stages of decline (class 1). Original photo scale = 1:5000.

to a lighter, paler hue. When trees reach damage classes 2 or 3 a number of white or gray colored branches appear throughout the crown. This discoloration is due to the presence of chlorotic foliage, defoliated branches, and branches containing a profuse growth of lichen (Grundmann 1984; Hartmann 1984; Masumy 1983) (Fig. 4).

Healthy silver fir appear as a dark red color on color-IR film. As this species begins to display decline symptoms, the foliage becomes progressively lighter in color and dead branches begin to appear in the crown. When a storks nest forms in the upper crown, it appears as a distinct circle of deep red color surrounded by a ring of dead, lichen covered branches (Grundmann 1984) (Fig. 4).

Scots pine, which is typically a red-brown color on color-IR film when healthy, also tends to take on a lighter, paler color as it progresses through the various stages of decline and as foliage is lost or becomes chlorotic. Top kill, caused by the pine bark blister rust fungus, Endocronartium pini, is visible as a distinct blue-green color similar to the way dead conifers appear after they have lost their needles, on color-IR photos taken over North American forests (Hartmann 1984).

As beech progresses through its stages of decline, its appearance on color-IR photos changes from a rounded crown with thick, bright red colored foliage to an open crown with light pink or magenta foliage. Individual, claw shaped branches (Spiesse) are often clearly visible in the crown of a class 1 (sickly) tree. Class 2 trees tend to have distinct clumps of foliage rather than an even, fine textured, crown. Class 3 trees have sparse, open crowns with only a few widely spaced limbs (Runkell and Roloff 1985).

FOREST DECLINE INVENTORIES WITH AERIAL PHOTOGRAPHS - The primary use of aerial photography in assessment of forest decline in West Germany is the conduct of regional and statewide inventories. While national statistics on the status of forest decline are presently derived from the nationwide ground inventory, a number of West German states have initiated aerial photo inventories to supplement the national survey and provide more detailed, site specific data. Survey designs are based on rating a fixed number of trees at a sample point rather than attempting to enumerate the number of dead and declining trees on a sample plot of known size; the approach usually used in the United States. Inventories have been conducted in most West German States and for individual forest districts or community forests. The approaches used in the states of Baden-Württemberg and Lower Saxony are reviewed in detail.

BADEN-WÜRTTEMBERG - The forest decline inventory used in Baden-Württemberg during 1983 is described by Hildebrandt and Kadro (1984). North-south flight lines, spaced at 8 km intervals were flown with CIR film at a photo scale of 1:5000 during late July. Flight lines coincided with the nationwide Gauss-Kruger survey grid. Aerial photos along each flight line were flown with a standard 60 percent overlap. Areas that were less than 10 percent forested were deleted from the flight plan. Aerial photo plots were established on every third photo along each flight line. These were located by placing a clear plastic overlay, marked with a series of circular plots, over the sample photo. Sample trees occurring closest to plot center were

identified as to species and rated for degree of decline using the standard five class rating system (Tables 1 and 2). Six sample plots of 20 trees each were classified on each photo. Additional data taken from the aerial photos at each plot location included:

elevation (taken from a topographic map);
slope and aspect;
topographic position;
age class and stand density;
forest type; and
location of plot within stand (edge, middle, adjacent to opening, etc.).

In 1984, the nations of the European Economic Community recognized the desirability of a multinational forest decline inventory which would provide data that could be compared between member nations. The procedure developed for Baden-Württemberg was pilot tested as a multinational forest decline inventory technique in 1985 in the Black Forest. The only change in inventory design was that nine plots of 15 trees each were examined on every third photo instead of six plots of 20 trees each. Additional pilot tests of essentially the same survey technique are underway for test sites in Belgium/Luxemburg, and France (Hildebrandt 1985b).

LOWER SAXONY - The statewide forest decline inventory using aerial photography in Lower Saxony is described by Hartmann (1984). This inventory has, to date, provided data on the status of decline in Norway spruce and Scots pine by major forest regions of the state (Hartmann and Voretzsch 1985). Aerial photo coverage is somewhat more intensive and considerably more variable in Lower Saxony than in Baden-Württemberg, primarily because most of the forested area occurs in the eastern portion of the state. Most areas are flown on north-south flight lines at 4 km intervals, again coinciding with the Gauss-Kruger survey grid. The Harz Mountains, a region of extensive Norway spruce plantations and severe forest decline located in the southeastern corner of Lower Saxony, is flown on north-south flight lines at 2 km intervals. Areas of more scattered forest land in western Lower Saxony are simply flown to cover as much forest land as possible. Flight lines may be of any orientation in order to maximize coverage. Photo scale is 1:6000 and all flight lines are flown with the standard 60 percent forward overlap.

One of the objectives of the aerial photo inventory of Lower Saxony is to obtain decline data on a stand basis. Detailed stand maps are available for all state forest lands and some municipal and private lands. Stand boundaries are transferred to aerial photos from topographic maps. A clear plastic dot grid containing 16 dots per hectare, is placed over sample stands. The tree nearest to each dot is selected as a sample tree and is identified as to species and given a decline rating. A slightly modified decline rating system is used in Lower Saxony. This system takes into account the presence of chlorosis, broken tops and top dieback. Detailed descriptions of each decline class are provided by Hartmann (1984) for both Norway spruce and Scots pine.

A large area, multiphase inventory system is under development by scientists at the University of Göttingen to measure a number of variables

associated with decline of Norway spruce in Lower Saxony. The purpose of this inventory is to estimate damage, document changes in stand structure, and estimate changes in stand growth over time. A three stage inventory system has been designed and is being tested. This includes use of CIR aerial photo plots, a subsample of ground plots to calibrate photo interpretation and acquire data on stand structure and increment, and finally, a subsample of each ground plot where trees can be destructively sampled for stem analyses (Kenneweg and Nagel 1983).

ASSESSING PATTERNS OF DECLINE WITH AERIAL PHOTOS - The location of areas of intensive decline symptoms relative to topography and sources of high concentrations of emissions is of particular interest when attempting to establish the causal agents responsible for decline. In a study of the northern Harz Mountains in Lower Saxony, Hartmann et al. (1985) describe the location of concentrated areas of chlorotic foliage on Norway spruce as determined from the interpretation of 1:6000 scale CIR aerial photos. These photos show distinct areas of chlorotic foliage on north and northeast facing slopes. The slopes directly face a region of smelters near the city of Goslar on the northern edge of the Harz Mountains which emit high levels of SO_2. The photos also clearly show lower intensities of chlorotic foliage in drainages. In one case, an aerial photo shows a distinct group of trees with normal foliage in the proximity of a spring. This group of trees is surrounded by an area of trees with chlorotic foliage.

TREND SURVEYS - The single most important advantage of aerial photos considered by West German foresters in assessment of forest decline is that they provide a permanent record of decline status at a given point in time. This provides an opportunity to assess change in decline status by sequential photography of permanent sample points. As part of the multiphase inventory being developed in Lower Saxony (Kenneweg and Nagel 1983), permanent sample trees are located and precisely fixed with an analytical plotter. Another technique, used both in Baden-Württemberg and Bavaria, is to make crown maps of a series of permanent sample plots (Fig. 5). Each tree is identified as to species and given a decline rating. These permanent aerial photo plots can be rephotographed periodically and used to provide an index of change in decline status (Marx 1985).

AGREEMENT WITH GROUND DATA - Ground data collected in conjunction with forest decline surveys using aerial photography is used primarily for development of photo interpretation keys and to maintain an informal check on accuracy of photo interpretation. Ground survey data are not integrated with aerial photo data using statistical procedures such as double sampling with regression (Wear et al. 1966) or multistage-single phase probability proportional to size sampling (White et al. 1983) as is commonly done with forest damage inventories conducted in the United States using aerial photos. However, a statistical integration of photo interpretation and ground survey data is being developed as part of the multi-national pilot inventory of forest decline underway in West Germany, France, and Belgium/Luxemburg (Hildebrandt 1985b).

One problem in statistical integration of photo and ground data arises from the fact that the same symptoms of forest decline cannot always be seen from

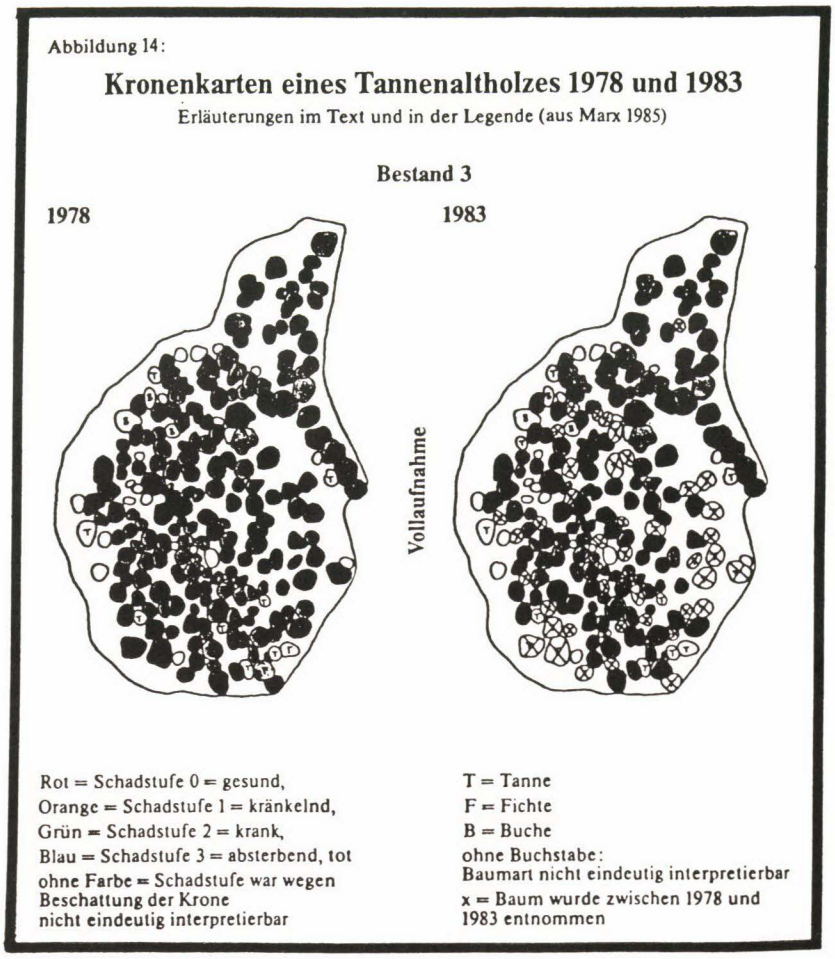
Abbildung 14:
Kronenkarten eines Tannenaltholzes 1978 und 1983
Erläuterungen im Text und in der Legende (aus Marx 1985)
Bestand 3
1978
1983
Vollaufnahme
Rot = Schadstufe 0 = gesund,
Orange = Schadstufe 1 = kränkelnd,
Grün = Schadstufe 2 = krank,
Blau = Schadstufe 3 = absterbend, tot
ohne Farbe = Schadstufe war wegen Beschattung der Krone nicht eindeutig interpretierbar
T = Tanne
F = Fichte
B = Buche
ohne Buchstabe: Baumart nicht eindeutig interpretierbar
x = Baum wurde zwischen 1978 und 1983 entnommen

Figure 5 - Example of a crown map made from aerial photographs used to monitor changes in decline status over time (Marx 1985).

both photo interpretation and the ground. It is generally believed in West Germany that the symptoms of forest decline are actually more visible on large scale CIR photos than they are from the ground. This is believed to be due to the fact that decline symptoms, especially in the early stages, are concentrated in the upper crown or, as in the case of Norway spruce, on the upper needle surfaces. Nevertheless, data derived on the status of forest decline as determined from aerial photos and independent ground inventories both in Lower Saxony and Baden-Württemberg in 1983, show comparable results (Hartmann 1984).

OPERATIONAL PROBLEMS - Several operational problems were identified by workers in West Germany in the use of large scale CIR aerial photos for assessment of forest decline. These include unfavorable weather during the designated photo acquisition period, inconsistent IR balance of CIR film, and problems associated with coordinating ground data acquisition with aerial photo interpretation. These same factors have also been identified as problems in the use of this technology for forest damage assessment in North America.

WEATHER - Unfavorable weather during the designated photo acquisition period was mentioned as the single most important factor limiting the use of

large scale CIR aerial photos for assessment of forest decline. This appears to be a more critical factor in the northern states which have a maritime climate strongly influenced by the Baltic and North Sea. In the state of Schleswig- Holstein, for example, photo coverage of the southern portion of the state was successfully acquired in 1983, a relatively dry year. During 1984 and 1985, years of normal or excess moisture, none of the planned photo missions could be conducted due to the absence of cloud free days. Similarly, in Lower Saxony, virtually all of the state was successfully photographed during 1983 but only limited areas could be flown during 1984 and 1985, again, because of the lack of cloud free days. Weather conditions are somewhat more favorable in the southern states of Baden-Württemberg and Bavaria; however, in 1985 only a portion of the planned photo coverage had been acquired in these states by early September.

IR BALANCE - Inconsistencies in the sensitivity of the cyan dye layer of CIR film can result in photos with a variable color balance. If the cyan layer is too active, the resulting film is too red. Film with a desensitized cyan layer will tend to have a blue cast. Both extremes result in reduced contrast between hardwoods and conifers and adversely affect the ability of photo interpreters to accurately classify declining trees.

In recent years, CIR film exposed both in North America and Europe for forest damage surveys has produced reasonably consistent results. In 1985, however, workers in Baden-Württemberg, Bavaria, and Lower Saxony reported having received processed film from their contractors with an excessive red color balance. CIR film with excessive red tones was also encountered in the United States during 1985 on some photo missions flown by the Forest Pest Management/Methods Application Group and the Doraville, Georgia, Field Office of the Southern Region's Forest Pest Management staff, USDA Forest Service. In addition to the photo interpretation problems mentioned in the preceeding paragraph, several West German workers complained of eye fatigue when working with photos with an excessive red color balance for prolonged periods.

The characteristics of CIR film and its inherent variability due to the instability of the cyan layer are documented in the literature (Fleming 1978; Fritz 1967). A method of pretesting a specific emulsion of CIR film using sensitometric analysis of the three dye layers to compute Log E is described by Fleming (1980). Procedures for correcting IR balance of film with a known overactive cyan layer include exposing the film through a Corning C3966, IR attenuating filter (Fritz 1967) or storage of the film at room temperature for a specified period. Storage of CIR film for one week at a temperature of 78° F. will raise the Log E value by .03[4/]. CIR film with a Log E value of .35 is considered to have an optimum IR balance.

Development also has an effect on color balance of CIR film. Several workers in West Germany reported that they could identify the film processor by the color balance of the film. One commercial processor consistently delivers film with a nearly optimum color balance, while the other delivers film with a slight orange cast.

[4/]Personal communication, John J. Graham, Eastman Kodak Company, Rochester, NY.

In an attempt to find a CIR film with a more consistent IR balance, workers at the Bavarian Forest Research Institute in Munich conducted a series of tests in 1985 with Kodak type SO-131 high definition aerial Ektachrome infrared film. Using a Hasselblad 70 mm camera, they obtained photos of a test site at scales of 1:5000, 1:10000, 1:18000, 1:40000, and 1:78000. The resultant series of photos shows that as photo scale gets smaller, the color balance of the film shifts to the blue since more and more IR radiation is absorbed by the additional atmosphere between camera and target. Comparison of the 1:5000 scale SO-131 film with 1:5000 scale Kodak type 2443 CIR film of the same test site showed that the SO-131 film had a superior color balance. This would provide better contrast between damage classes. Another test of SO-131 film was conducted in Bavaria with a conventional 230 mm (9-inch) format mapping camera, however the processed film had not been delivered as of September 1985.

COORDINATING AERIAL AND GROUND DATA - Processed film is often not received from contractors until mid or late September. By this time the onset of fall coloring of hardwoods has already begun, especially at the higher elevations. This severely limits the time available to acquire ground data for the development or revision of photo interpretation keys or to check on the accuracy of photo interpreters. In order to deal with this problem, workers in both Baden-Württemberg and Lower Saxony are collecting ground data during or prior to the photo acquisition period. A tree near the center of a sample plot is marked with a panel marker that is visible on the aerial photo. Panel markers are placed in the tops of trees by placing a string line across the top of the tree with a bow and arrow. This insures that photo interpreters locate their plots at precisely the same location as the ground plot, and the ground plot is subsequently used as an informal check on the accuracy of photo interpretation.

DIGITAL IMAGE ANALYSIS

Most workers in West Germany readily acknowledge that large scale CIR aerial photography is the best current remote sensing alternative for operational surveys to assess the status of forest decline. However, the use of computer assisted digital image analysis offers potential advantages over conventional aerial photo interpretation. Photo interpretation is a time consuming, often tedious task and photo interpreter fatigue is a problem in maintaining consistent data quality. Photo interpretation also tends to be subjective and the quality of data is strongly influenced by the individual training and experience of photo interpreters and the quality of the film. The latter factor is regarded by West German remote sensing specialists as having both positive and negative effects on the data capture process. These considerations have led researchers at the Departments of Photogrammetry and Remote Sensing of the Universities of Freiburg and Munich and the German Aerospace Research Center (DFVLR) in Oberpaffenhoffen to investigate the potential of computer aided classification of digital data for assessment of forest decline over large areas. Status of current research on this technology for assessment of forest decline in West Germany is summarized in papers by Hildebrandt and Kadro (1984), Kadro (1984, 1985), Kadro and Kuntz (1985), and Koch et al. (1984).

AIRBORNE MULTI-SPECTRAL SCANNERS - In 1983, a Bendix M^2S Multispectral Scanner (MSS) was modified by the DFVLR to provide data which simulates the Thematic Mapper (TM) aboard LANDSAT D. This unit was flown over Norway spruce and silver fir stands in the Black Forest known to have extensive damage. The scanner was flown at three flying heights; 300m, 1000m, and 4000m above mean terrain elevation. This provided scenes with pixel sizes of 0.75 x 0.75m, 2.5 x 2.5m, and 10 x 10m respectively. At the 300m flying height, individual tree crowns and stands could be resolved and classified. At the remaining two flying heights only stands could be resolved and classified.

Comparison of spectral signatures on airborne multispectral scanner data images of healthy versus damaged or declining Norway spruce and silver fir shows a classic reflectance pattern. The reflectance of declining trees decreases in the visible portion of the electromagnetic spectrum (0.4 to 0.7 micrometers) when compared to healthy trees. In the near infrared portion of the spectrum (0.7 to 1.1 micrometers) reflectance of declining trees decreases relative to healthy trees. In the middle infrared region (1.65 to 2.2 micrometers) the spectral reflectance of declining trees is once again higher than healthy trees. This is true both for individual trees and stands (Kadro 1984). In situ field spectrometer data from healthy and declining red spruce in Vermont show a similar reflectance pattern (Rock et al. 1985).

A supervised maximum likelihood classification system was used to classify forest vegetation and status of decline in selected spruce and fir stands in the Black Forest on the airborne multispectral scanner data. At least one source of classification error has been documented; the classification of beech as healthy fir. This is believed to be due to differences in the illumination of individual tree crowns (Kadro 1984). A Daedalus AADS 1268 Airborne Thematic Mapper is now available and will be flown over test sites in 1986.

LANDSAT THEMATIC MAPPER - Work is currently underway at the University of Freiburg to classify forest decline on TM simulated data collected during the summer of 1983, 84, and 85 and 1984 Landsat TM data taken over the Black Forest and the neighboring Alsace-Lorraine region of France. Early results confirm that hardwood and conifer forests can be reliably separated and there are indications that areas of trees in damage classes 0 and 1 can be separated from damage classes 2 and 3 in Norway spruce and silver fir forests. One drawback of the classification of forest decline with TM data however, is that the present classification system is incapable of classifying vegetation type or condition in shaded areas. LANDSAT D passes over central Europe at approximately 9:30 a.m. local time and west facing slopes are still in shadow at that time. It is estimated that approximately one-third of the area in TM scenes of the Black Forest and Alsace-Lorraine test sites have been classified as shadow. This can limit the usefulness of satellite imagery for forest damage classification, especially if one of the objectives of an assessment is to evaluate damage relative to slope, aspect, or proximity to a pollution source. This work is continuing and will include a cooperative study with the Jet Propulsion Laboratory in Pasadena, California, flying a NASA aircraft with an airborne imaging spectrometer over the Black Forest test site during the summer of 1986.

DISCUSSION

EUROPEAN VERSUS NORTH AMERICAN FORESTS - SOME SIMILARITIES AND CONTRASTS

The forests of North America and Europe are similar in that all of the genera of trees indigenous to European forests are also represented in North American forest ecosystems. Genera such as Abies, Betula, Fagus, Larix, Picea, Pinus, Populus, and Quercus are either of considerable economic importance or cover large areas of forest land on both continents. Representative species in tree genera common to both continents also tend to occupy somewhat similar ecological niches. Pinus and Populus, for example, tend to be shade intolerant, pioneer species, whereas representatives of the genus Picea and Fagus are tolerant, climax species both in Europe and North America.

Forests on both continents are subject to damage by similar biotic agents. Barkbeetles, a variety of lepidopterous and hymenoterous defoliators, regeneration weevils, and other insects can be of economic importance on both continents. Similarly, several genera of fungi capable of causing forest damage are common to both continents. Of particular note are the root fungi, Fomes annosus and Armellaria sp., which occur both in European and North American forests. Forest ecosystems in Europe and eastern North America have been subject to a number of forest declines in recent years. These commonalities form a strong basis for mutual interest and exchange of scientific data, some of which may have direct application on both continents.

There are also many differences between the forests of Europe and North America. These differences limit the direct application of much of the scientific knowledge developed on one continent to application on the other.

While trees of the same genera are represented on both continents, European forest ecosystems have relatively few species. In West Germany, approximately 20 species are considered to be of economic importance and only five; Norway spruce, silver fir, Scots pine, beech and oak, are of major importance. North American forests, on the other hand, are considerably more diverse with large areas of forests commonly composed of many species. This is especially true of the hardwood forests of the eastern United States where over 100 species of commercial importance may be found in parts of the central and southern Appalachian Mountains.

Forests of central Europe, especially West Germany, have been under intensive management for over two centuries. Most forests are of plantation origin, consequently there are large areas of single species, regulated stands which are managed to maximize timber production as well as provide a recreation experience and wildlife habitat. These forests are well roaded and readily accessible. During the past 40 years pest management activities which emphasize prevention of pest losses have been implemented. Wind and snow broken trees, which can serve as breeding sites for barkbeetles are promptly removed. Spruce logs are routinely peeled at log landings to prevent attack by the barkbeetle Ips typographus. Pheromone traps are widely used to survey

for defoliating insects or to trap out potentially destructive barkbeetles. As a result, outbreaks of destructive insects and disease occur at a much lower frequency and are less severe than in the forests of North America. The relative lack of classic biotic forest damage in West German forests makes the task of detecting and assessing a forest decline of abiotic origin, with symptoms that are subtle when compared to damage caused by barkbeetles or defoliating insects, more feasible.

North American forests, on the other hand, still consist of large areas of wild, unmanaged, or extensively managed lands. Many forest lands still have little or no access, limiting opportunities for timely harvesting or implementation of preventative pest management tactics. In addition, an effective wildfire suppression program has altered the density and composition of many forests, especially in the west, thus increasing their susceptibility to a variety of biotic pests. Outbreaks of insects such as spruce budworms, Choristoneura sp., the mountain pine beetle, Dendroctonus ponderosae, or southern pine beetle, D. frontalis, often covering millions of hectares, are reported annually in North American forests. A survey system, designed to assess vegetation damage caused by a complex of atmospheric pollutants in North America, must take into account the probability of widespread occurrence of these biotic pests.

OPPORTUNITIES FOR APPLYING WEST GERMAN INVENTORY METHODS

Of the various approaches currently used to assess the status of forest decline in West Germany, the use of a combined aerial photo-ground survey seems to offer the greatest potential for application in the United States, assuming that air pollution related forest declines will produce aerially visible symptoms. This approach has already been used on a limited basis for the assessment of specific decline problems in the eastern United States (Ciesla et al. 1985; Weiss et al. 1985). The limited access in many forested areas of the United States makes the use of a survey method using exclusively ground techniques less attractive, especially if surveys are to be conducted at fairly frequent intervals to obtain trend data. Use of remote sensing techniques such as computer assisted analysis of multispectral data for forest damage assessment is still in the research stage both in Europe and North America. Consequently, this technology presently offers little or no opportunity for operational use.

Surveys designed to assess status of forest decline and damage in West Germany emphasize classification of the condition of living trees. The decline symptoms tend to occur in the upper crown or on the upper surfaces of the foliage making them readily visible on large scale CIR aerial photos. The basic design, which calls for the assessment of a fixed number of trees at a sample site, allows photo interpreters to concentrate their attention on a small number of trees. The photo interpretation keys which have been developed by West German scientists provide detailed guides for damage classification. This approach is worthy of testing under North American forest conditions.

Ability to identify tree species on CIR aerial photos is an integral part of the West German forest decline inventory. The relatively small number of

tree species present in West German forests is certainly an advantage here. In addition, most of the species have distinct crown and foliage characteristics which are easily recognizable on large or medium scale CIR aerial photos. Despite the fact that a number of photo interpretation guides have been published for tree species identification in various parts of North America, the relatively large number of tree species indigenous to these forests will increase the complexity of species identification on aerial photos by several orders of magnitude. Attempts to identify coniferous genera in the northeastern United States on medium scale CIR aerial photos in conjunction with a forest decline survey has been reasonably satisfactory (Weiss et al 1985). However, the identification of hardwoods to species on aerial photos presents a significantly more complex problem. Perhaps the best that can be expected in the United States is to classify hardwoods into broad species groups, i.e., maples, oaks, hickories, etc.

The successful use of CIR aerial photos for forest decline assessment in West Germany is based upon acquisition of large scale (1:5000-1:6000), high quality photos. Use of aerial cameras with long focal length lenses (30 cm) minimizes edge distortion and increases overall photo quality. In the United States, there has been a trend toward use of smaller scale aerial photos for forest damage assessment in order to increase area coverage. For example, the spruce decline inventory of the northeastern United States which has been referred to earlier in this paper (Weiss et al. 1985) was conducted with 1:8000 scale CIR photos. A scale of 1:8000 was determined to be satisfactory for detection of hardwoods with top dieback or mortality in Vermont (Ciesla et al. 1985); however, this scale is probably not adequate for detection and classification of more subtle symptoms such as crown thinning, slightly chlorotic or discolored foliage. The effect of decreasing photo scale on the ability to classify the more subtle types of forest damage is discussed in depth by Murtha (1983). If these symptoms are to be detected on aerial photos, it will be necessary to use photo scales in the range of 1:4000 to 1:6000. Most 230 mm format aerial photography flown for forest damage surveys in the United States is acquired with mapping cameras equipped with either 15 cm (6-inch) or 21 cm (8.25-inch) focal length lenses. Use of an aerial camera with a 30 cm lens, at least in the relatively low elevations typical of the eastern United States, would reduce edge distortion. Use of aerial cameras with a forward image motion compensation capability would significantly increase image quality.

Maintaining consistent IR balance of CIR film is a continuing problem both in Europe and North America. Consistent color balance is critical for detection and classification of subtle decline symptoms. It may be necessary to implement the sensitometric testing procedures described by Fleming (1980) both in Europe and North America to insure consistent IR balance of CIR film used for forest decline inventories.

The use of less formal ground surveys to accompany aerial photo interpretation may be worthy of consideration in future forest decline inventories conducted in North America. This phase of a forest damage inventory is often the most time consuming and costly. The classification of a fixed number of trees at a photo sample point, as is currently done in West Germany, eliminates a major source of omission error inherent in the

enumeration of dead and declining trees on a fixed area plot, the failure of photo interpreters to detect and count all of the damaged trees on a plot. In addition, if the assumption that decline symptoms are actually more visible on aerial photos than from the ground also holds true for North American forest declines, the need for formal supplemental ground surveys may not be as critical; however, this hypothesis will have to be formally tested.

INTERPRETATION OF DECLINE DATA

National statistics on the status of forest decline in West Germany show all trees in damage classes 1, 2, 3 and 4 as damaged. Damage class 1, 10 to 25 percent foliage loss, is considered by many West German foresters as a questionable damage class. Trees in this class may be responding to local site or stand related stresses. Forest damage statistics for West Germany in 1984 show that the greatest proportion of damaged trees in both 1983 and 1984 were in damage class 1. Also, the greatest change in status of decline from 1983 to 1984 was an increase in the proportion of trees listed in class 1 in 1984. The proportion of trees in damage classes 2, 3, and 4 remained fairly constant (Anonymous 1984b).

The relatively high proportion of extensively managed or unmanaged stands in the United States, with an accompanying higher incidence of biotic pests, would be expected to contain a significant proportion of trees with a 10 to 25 percent foliage loss. To include a damage class of 10-25 percent in a national reporting system on the condition of forest vegetation in the United States as "damaged vegetation" could inadvertently include a high proportion of low level damage caused by biotic agents or site related factors.

ACKNOWLEDGMENTS

Sincere thanks are extended to the many West German foresters, research scientists, and remote sensing specialists who so willingly shared their technical expertise and experiences during this visit. Special thanks are extended to Prof. Dr. Hartmud Kenneweg, Berlin Technical University; Horst Höhne, Schleswig-Holstein State Forest Service, Kiel; Dr. Günther Hartmann, Lower Saxony Forest Research Center, Göttingen; Armin Troycke, Bavarian Forest Research Center, Munich; and Dr. Georges Kritikos, German Aerospace Research Center, Oberpaffenhoffen, who hosted various portions of this visit.

Thanks are also due to Dr. A. Kadro, Department of Photo Interpretation and Remote Sensing, University of Freiburg; Dr. Joseph Ulliman, University of Idaho, Moscow (currently on sabbatical leave at the University of Freiburg); Ray Allison, Remote Sensing Coordinator, USDA Forest Service, Washington, D.C.; Dr. Kenneth A. Knauer and Robert Loomis, USDA Forest Service, Forest Pest Management, Washington, D.C.; and Manfred E. Mielke, USDA Forest Service, Forest Pest Management, Morgantown, West Virginia, for their constructive reviews of this paper.

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☆U.S. GOVERNMENT PRINTING OFFICE:1986—677-920